Carnegie Mellon University Africa
Certificate I: Understanding AI and Machine Learning in Africa

Course AIML02: AI and Machine Learning in Africa

Module 02: Application Case Studies
Lecture 02: Logistics

Welcome to Lecture 2 of Module 2, in which we are examining case studies of the application of AI and machine learning in Africa.

In this lecture, we will focus on a case study in logistics, looking at the role that unmanned aerial vehicles, or drones, are playing in the delivery of goods in Africa. Specifically, we will be looking at the way that Zipline's medical delivery drones are changing the way blood products are delivered in Rwanda.

This lecture is slightly different from some of the other case study lectures in that we won't be focussing on the underlying AI techniques – there are no mathematical equations – but instead we will be concentrating on the functionality of the system and the benefits that it brings.

We introduce the target article for the case study and explain how Zipline, a startup based in California, have built and operate a drone delivery service for blood products in rural Rwanda. We then take a closer look at the modular components of a Zipline drone: the Zip, as it's called.

Having established the engineering accomplishments of the Zipline operations, we note that technical excellence on its own is not enough for long-term success and we consider the business side of Zipline's operation as it plans to roll out its services in other countries in Africa, and beyond.

We finish up by summarizing what we have covered and identifying the articles that you should read to consolidate what you have learned.

Once you have listened to this lecture and read the commentary that accompanies each slide, we strongly recommend you watch the accompanying video, after which you should read the target article, and then listen to the lecture again.

We have four learning objectives, so that, after studying the material covered in this lecture, you should be able to do the following.

1. Explain the operation of the Zipline blood delivery operation in Rwanda.

2. Identify the benefits of delivery by drone in rural environments.

3. Explain the different components of a Zipline drone.

4. Discuss the importance of a business model for the viability of a drone service.

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In this lecture, we will focus on a case study in logistics, looking at the role that unmanned aerial vehicles, or drones, are playing in the delivery of goods in Africa.

Specifically, we will be looking at the way that Zipline's medical delivery drones are changing the way blood products are delivered in Rwanda.

Slide 2 This case study is based on an article entitled: "In the air with Zipline's medical delivery drones"

written by Evan Ackerman and Michael Koziol, and published online in 2019 in IEEE Spectrum 2019.

It appeared in the print edition in May with the title "The Blood is Here".

The article demonstrates how unmanned aerial vehicles – drones – can play an important role in timely delivery of critical supplies to remote rural locations and explains the engineering accomplishments necessary to bring that about.

Slide 3 Delivery by drone is a futuristic idea that has caught people's imagination.

Amazon, Google, and Domino's Pizza have all given carefully controlled demonstrations of drones delivering their products

The question is: can a company find a business model that makes drone delivery a sustainable and profitable activity?

Slide 4 Zipline could be that company. It is delivering blood to 25 hospitals and clinics across the country every day.

It is betting that delivering lifesaving medical supplies, which are often lightweight and urgently needed, will be the killer app for delivery drones.

Slide 5 For hospitals in need of critical medical supplies, Rwanda's dirt roads pose a problem, especially in the rainy season.

Blood and blood products have a short shelf life and strict storage requirements.

It is difficult to predict how many packs of each blood type will be needed at a given facility, and when they will be needed.

Slide 6 On-demand delivery from a central storage location offers a viable solution.

However, in an emergency, it can take up to 5 hours for a Rwandan hospital to receive a blood delivery via road.

This delay can mean the difference of life and death for the patient.

Slide 7 On-demand delivery by drones is a viable alternative

and Rwanda is the ideal test bed, with its challenging terrain, relatively small size, extensive wireless connectivity, and receptive government.

Slide 8 Zipline has two fulfillment centers in Rwanda, which it refers to as “nests.”

The Muhanga nest, which we visited, is about 50 km

from the capital of Kigali.

Slide 9 When an order comes in from a hospital via phone, website, WhatsApp, or SMS, a worker wraps the needed packs in padding and places the bundle into a bright red box, which has a wax-paper parachute attached.

Slide 10 A technician places the box and parachute in the belly of a drone behind a spring-loaded hatch,

then snaps a modular battery pack into the drone’s nose.

Slice 11 Two people carry the drone to a 13-meter-long electric catapult powered by a bank of supercapacitors, then run through a preflight checklist with the aid of a smartphone app.

Slide 12 Zipline confirms the drone’s flight plan with the Rwanda Civil Aviation Authority and requests flight clearance,

Finally, the catapult flings the drone skyward, accelerating it to 100 kilometers per hour in half a second.

It swiftly rises over the Rwandan countryside to a cruising altitude of 120 meters.
At Muhanga, this happens 20 to 30 times a day.

Slide 13 Here is a short overview of this process from the video that features in the last slide of this lecture.

Slide 14 As soon as a drone leaves the catapult, it's fully autonomous.

While both Zipline and the Rwanda Civil Aviation Authority track the aircraft and can redirect it at any time, in practice the Zips are mostly forgotten about until they return home, mission complete.

Slide 15 In the air, each Zip follows a predetermined flight plan, relaying data on its position and status through Rwanda's wireless network.

Crucially, it also stores sensor data from all its control instruments: approximately 1GB of data per hour of flight. This is subsequently analyzed to identify ways of improving the Zip's performance.

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Slide 16 About 5 minutes before the drone arrives, hospital staff members get an automatic text alert telling them to send someone outside to await the delivery.

Slide 17 After the pack parachutes safely to the landing point

Slide 18 it is picked up by staff at the clinic or hospital, as the Zip returns safely back to base.

Here is a video of a drop at a medical clinic in rural Rwanda.

Slide 19 [play video]

Slide 20 Launching a fixed-wing drone from a catapult is relatively straightforward, but landing it safely—without landing gear or a lengthy runway—is a challenge.

Zipline's solution is a recovery system comprising two 10-meter-high truss towers, each having a vertically rotating arm, and a cable is strung between the arms.

As a returning Zip flies between these two towers, the arms rotate upward in a fraction of a second, so that a tiny metal hook below the Zip's tail snags the cable, bringing the Zip to a stop within a few meters, and allowing it to drop safely to a suspended position.

This process is captured in a slow-motion in the video that features in the last slide of this lecture.

Here's an excerpt from it.

Slide 21 [Play video]

Slide 22 Zips are modular.

When an order comes in, technicians snap together the three main components:

the lightweight foam chassis [1], the wings [2], and the battery unit [3], which also contains the flight plan and the GPS unit.

Scanning QR codes [4] initiates automatic preflight tests of the drone's systems.

To keep the drone flying in the event of a minor mechanical failure, it has two motors [5] and redundant ailerons [6] on the wings that help maintain flight control.

The drone's cargo compartment [7] contains the package of blood until it's parachuted down to the delivery site.

To eliminate the need for a lengthy runway for takeoffs and landings, an electric catapult launches the drone, and a wire strung between towers captures the returning drone by snagging a 3-centimeter metal hook [8] on the drone's tail.

Slide 23 While the technology that makes drone delivery possible is impressive, as we learned in AIML01, that's only part of the study. Innovation requires adoption and a viable business model.

Zipline currently receives subsidies from the Government of Rwanda to make its service affordable for hospitals.

Blood deliveries by drone are currently more expensive than routine deliveries by ground vehicle, such as motor bikes, partly because ground vehicles can carry a much bigger load.

Slide 24 Nevertheless, cost and sustainability are the key issues as Zipline seeks to expand its delivery services to more African countries,

Its first expansion effort, in Tanzania in 2018, fell through during contract negotiations with the government.

But at the end of 2018, the government of Ghana approved a four-year contract to deliver blood and other medical supplies by drone, worth an estimated US $12.5 million for Zipline.

The plan for Ghana calls for four fulfillment centers that will make between 100 and 150 deliveries per day. The Ghanaian government estimates a per-delivery cost of $17.

Slide 25 Zipline makes the case that, in the long run, minimizing waste in the medical system will help the drones pay for themselves.

In Rwanda, the cost to collect, test, and store a unit of blood is about $80. Before Zipline began operations, about 7 percent of blood packs expired without being used, costing the Rwandan government more than $1 million annually.

In 2018, the hospitals that Zipline serves wasted no blood packs at all.

Slide 26 Here is how the authors conclude their article

"In the distance, we can hear the faint buzz of another Zip returning home after making its delivery of blood. Anywhere else on Earth, it would be futuristic. In rural Rwanda, it’s just routine."

To summarize:

1. The article demonstrates that unmanned aerial vehicles – drones – can play an important role in timely delivery of critical medical supplies to remote rural locations.

2. It highlights the many engineering accomplishments necessary to realize an effective service.

3. It also highlights the importance of a viable business model to complement the engineering innovation.

Here is the target article used for the case study. Please read it carefully.

Ackerman E, and Koziol M (2019) The blood is here. IEEE Spectrum 56(5): 24–31, May.

This is the online version.

Ackerman E, and Koziol M (2019) In the air with Zipline's medical delivery drones. IEEE Spectrum online, April.
https://spectrum.ieee.org/in-the-air-with-ziplines-medical-delivery-drones

Here is a highly-recommended video highlighting the engineering accomplishments of the Zipline operation in Rwanda.

How Rwanda Built A Drone Delivery Service
https://www.youtube.com/watch?v=jEbRVNxL44c